$$I = \frac{T_s \, V_{m(std)} \, P_{std} \, 100}{T_{std} \, v_s \, 2 \, A_n \, P_s \, 60 \, (1 - B_{ws})}$$

$$= K_5 \frac{T_s \, V_{m(std)}}{P_s \, v_s \, A_n \, 2 \, (1 - B_{ws})} \qquad \textbf{Eq. 5-8}$$

where:

K_5 = 4.320 for metric units,

= 0.09450 for English units.

12.11.3 Acceptable Results. If 90 percent ≤ I ≤ 110 percent, the results are acceptable. If the PM results are low in comparison to the standard, and "I" is over 110 percent or less than 90 percent, the Administrator may opt to accept the results. Reference 4 in Section 17.0 may be used to make acceptability judgments. If "I" is judged to be unacceptable, reject the results, and repeat the sampling run.

12.12 Stack Gas Velocity and Volumetric Flow Rate. Calculate the average stack gas velocity and volumetric flow rate, if needed, using data obtained in this method and the equations in Sections 12.3 and 12.4 of Method 2.

13.0 Method Performance. [Reserved]

14.0 Pollution Prevention. [Reserved]

15.0 Waste Management. [Reserved]

16.0 Alternative Procedures.

16.1 Dry Gas Meter as a Calibration Standard. A DGM may be used as a calibration standard for volume measurements in place of the wet test meter specified in Section 10.3, provided that it is calibrated initially and recalibrated periodically as follows:

16.1.1 Standard Dry Gas Meter Calibration.

16.1.1.1. The DGM to be calibrated and used as a secondary reference meter should be of high quality and have an appropriately sized capacity [*e.g.*, 3 liters/rev (0.1 ft^3/rev)]. A spirometer [400 liters (14 ft^3) or more capacity], or equivalent, may be used for this calibration, although a wet test meter is usually more practical. The wet test meter should have a capacity of 30 liters/rev (1 ft^3/rev) and capable of measuring volume to within 1.0 percent. Wet test meters should be checked against a spirometer or a liquid displacement meter to ensure the accuracy of the wet test meter. Spirometers or wet test meters of other sizes may be used, provided that the specified accuracies of the procedure are maintained.

16.1.1.2 Set up the components as shown in Figure 5-7. A spirometer, or equivalent, may be used in place of the wet test meter in the system. Run the pump for at least 5 minutes at a flow rate of about 10 liters/min (0.35 cfm) to condition the interior surface of the wet test meter. The pressure drop indicated by the manometer at the inlet side of the DGM should be minimized [no greater than 100 mm H_2O (4 in. H_2O) at a flow rate of 30 liters/min (1 cfm)]. This can be accomplished by using large diameter tubing connections and straight pipe fittings.

16.1.1.3 Collect the data as shown in the example data sheet (see Figure 5-8). Make triplicate runs at each of the flow rates and at no less than five different flow rates. The range of flow rates should be between 10 and 34 liters/min (0.35 and 1.2 cfm) or over the expected operating range.

16.1.1.4 Calculate flow rate, Q, for each run using the wet test meter volume, V_w, and the run time, 2. Calculate the DGM coefficient, Y_{ds}, for each run. These calculations are as follows:

$$Q = K_1 \frac{P_{bar}\ V_w}{(T_w + T_{std})\ 2} \qquad \textbf{Eq. 5-9}$$

$$Y_{ds} = \frac{V_w\ (T_{ds} + T_{std})\ P_{bar}}{V_{ds}\ (T_w + T_{std}) \left(P_{bar} + \frac{)p}{13.6} \right)} \qquad \textbf{Eq. 5-10}$$

where:

K_1 = 0.3858 °C/mm Hg for metric units

= 17.64 °F/in. Hg for English units.

V_w = Wet test meter volume, liter (ft^3).

V_{ds} = Dry gas meter volume, liter (ft^3).

T_{ds} = Average dry gas meter temperature, °C (°F).

T_{adj} = 273 °C for metric units

= 460 °F for English units.

T_w = Average wet test meter temperature, °C (°F)

P_{bar} = Barometric pressure, mm Hg (in. Hg).

)p = Dry gas meter inlet differential pressure, mm H_2O (in. H_2O).

2 = Run time, min.

16.1.1.5 Compare the three Y_{ds} values at each of the flow rates and determine the maximum and minimum values. The difference between the maximum and minimum values at each flow rate should be no greater than 0.030. Extra sets of triplicate runs may be made in order to complete this requirement. In addition, the meter coefficients should be between 0.95 and 1.05. If these specifications cannot be met in three sets of successive triplicate runs, the meter is not suitable as a calibration standard and should not be used as such. If these specifications are met, average the three Y_{ds} values at each flow rate resulting in no less than five average meter coefficients, Y_{ds}.

16.1.1.6 Prepare a curve of meter coefficient, Y_{ds}, versus flow rate, Q, for the DGM. This curve shall be used as a reference when the meter is used to calibrate other DGMs and to determine whether recalibration is required.

16.1.2 Standard Dry Gas Meter Recalibration.

16.1.2.1 Recalibrate the standard DGM against a wet test meter or spirometer annually or after every 200 hours of operation, whichever comes first. This requirement is valid provided the standard DGM is kept in a laboratory and, if transported, cared for as any other laboratory instrument. Abuse to the standard meter may cause a change in the calibration and will require more frequent recalibrations.

16.1.2.2 As an alternative to full recalibration, a two-point calibration check may be made. Follow the same procedure and equipment arrangement as for a full recalibration, but run the meter at only two flow rates [suggested rates are 14 and 30 liters/min (0.5 and 1.0 cfm)]. Calculate the meter coefficients for these two points, and compare the values with the meter calibration curve. If the two coefficients are within 1.5 percent of the calibration curve values at the same flow rates, the meter need not be recalibrated until the next date for a recalibration check.

16.2 Critical Orifices As Calibration Standards. Critical orifices may be used as calibration standards in place of the wet test meter specified in Section 16.1, provided that they are selected, calibrated, and used as follows:

16.2.1 Selection of Critical Orifices.

16.2.1.1 The procedure that follows describes the use of hypodermic needles or stainless steel needle tubings which have been found suitable for use as critical orifices. Other materials and critical orifice designs may be used provided the orifices act as true critical orifices (*i.e.*, a critical vacuum can be obtained, as described in Section 16.2.2.2.3). Select five critical orifices that are appropriately sized to cover the range of flow rates between 10 and 34 liters/min (0.35 and 1.2 cfm) or the expected operating range. Two of the critical orifices should bracket the expected operating range. A minimum of three critical orifices will be needed to calibrate a Method 5 DGM; the other two critical orifices can serve as spares and provide better selection for bracketing the range of operating flow rates. The needle sizes and tubing lengths shown in Table 5-1 in Section 18.0 give the approximate flow rates.

16.2.1.2 These needles can be adapted to a Method 5 type sampling train as follows: Insert a serum bottle stopper, 13 by 20 mm sleeve type, into a ½-inch Swagelok (or equivalent) quick connect. Insert the needle into the stopper as shown in Figure 5-9.

16.2.2 Critical Orifice Calibration. The procedure described in this section uses the Method 5 meter box configuration with a DGM as described in Section 6.1.1.9 to calibrate the critical orifices. Other schemes may be used, subject to the approval of the Administrator.

16.2.2.1 Calibration of Meter Box. The critical orifices must be calibrated in the same configuration as they will be used (*i.e.*, there should be no connections to the inlet of the orifice).

16.2.2.1.1 Before calibrating the meter box, leak check the system as follows: Fully open the coarse adjust valve, and completely close the by-pass valve. Plug the inlet. Then turn on the pump, and determine whether there is any leakage. The leakage rate shall be zero (*i.e.*, no detectable movement of the DGM dial shall be seen for 1 minute).

16.2.2.1.2 Check also for leakages in that portion of the sampling train between the pump and the orifice meter. See Section 8.4.1 for the procedure; make any corrections, if necessary. If leakage is detected, check for cracked gaskets, loose fittings, worn O-rings, etc., and make the necessary repairs.

16.2.2.1.3 After determining that the meter box is leakless, calibrate the meter box according to the procedure given in Section 10.3. Make sure that the wet test meter meets the requirements stated in Section 16.1.1.1. Check the water level in the wet test meter. Record the DGM calibration factor, Y.

16.2.2.2 Calibration of Critical Orifices. Set up the apparatus as shown in Figure 5-10.

16.2.2.2.1 Allow a warm-up time of 15 minutes. This step is important to equilibrate the temperature conditions through the DGM.

16.2.2.2.2 Leak check the system as in Section 16.2.2.1.1. The leakage rate shall be zero.

16.2.2.2.3 Before calibrating the critical orifice, determine its suitability and the appropriate operating vacuum as follows: Turn on the pump, fully open the coarse adjust valve, and adjust the by-pass valve to give a vacuum reading corresponding to about half of atmospheric pressure. Observe the meter box orifice manometer reading,)H. Slowly increase the vacuum reading until a stable reading is obtained on the meter box orifice manometer. Record the critical vacuum for each orifice. Orifices that do not reach a critical value shall not be used.

16.2.2.2.4 Obtain the barometric pressure using a barometer as described in Section 6.1.2. Record the barometric pressure, P_{bar}, in mm Hg (in. Hg).

16.2.2.2.5 Conduct duplicate runs at a vacuum of 25 to 50 mm Hg (1 to 2 in. Hg) above the critical vacuum. The runs shall be at least 5 minutes each. The DGM volume readings shall be in increments of complete revolutions of the DGM. As a guideline, the times should not differ by more than 3.0 seconds (this includes allowance for changes in the DGM temperatures) to achieve ± 0.5 percent in K' (see Eq. 5-11). Record the information listed in Figure 5-11.

16.2.2.2.6 Calculate K' using Equation 5-11.

$$K' = \frac{K_1 \, V_m \, Y \, (P_{bar} + \frac{)H}{13.6}) \, T_{amb}^{1/2}}{P_{bar} \, T_m \, 2} \qquad \textbf{Eq. 5-11}$$

where:

K' = Critical orifice coefficient, $[m^3)(°K)^{½}]/[(mm Hg)(min)]$ $\{[(ft^3)(°R)^{½})]/[(in. Hg)(min)]\}$.

T_{amb} = Absolute ambient temperature, °K (°R).

Calculate the arithmetic mean of the K' values. The individual K' values should not differ by more than ±0.5 percent from the mean value.

16.2.3 Using the Critical Orifices as Calibration Standards.

16.2.3.1 Record the barometric pressure.

16.2.3.2 Calibrate the metering system according to the procedure outlined in Section 16.2.2. Record the information listed in Figure 5-12.

16.2.3.3 Calculate the standard volumes of air passed through the DGM and the critical orifices, and calculate the DGM calibration factor, Y, using the equations below:

$$V_{m(std)} = \frac{K_1 V_m \left| P_{bar} + \left(\frac{)H}{13.6}\right) \right|}{T_m} \qquad \textbf{Eq. 5-12}$$

$$V_{cr(std)} = K_1 \frac{P_{bar}\ 1}{\sqrt{T_{amb}}} \qquad \textbf{Eq. 5-13}$$

$$Y = \frac{V_{cr(std)}}{V_{m(std)}} \qquad \textbf{Eq. 5-14}$$

where:

$V_{cr(std)}$ = Volume of gas sample passed through the critical orifice, corrected to standard conditions, dscm (dscf).

K_1 = 0.3858 K/mm Hg for metric units

= 17.64 °R/in. Hg for English units.

16.2.3.4 Average the DGM calibration values for each of the flow rates. The calibration factor, Y, at each of the flow rates should not differ by more than ± 2 percent from the average.

16.2.3.5 To determine the need for recalibrating the critical orifices, compare the DGM Y factors obtained from two adjacent orifices each time a DGM is calibrated; for example, when checking orifice 13/2.5, use orifices 12/10.2 and 13/5.1. If any critical orifice yields a DGM Y factor differing by more than 2 percent from the others, recalibrate the critical orifice according to Section 16.2.2.

17.0 References.

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18.0 Tables, Diagrams, Flowcharts, and Validation Data.

TABLE 5-1. FLOW RATES FOR VARIOUS NEEDLE SIZES AND TUBE LENGTHS.

Gauge/cm	Flow rate liters/min.	Gauge/cm	Flow rate liters/min.
12/7.6	32.56	14/2.5	19.54
12/10.2	30.02	14/5.1	17.27
13/2.5	25.77	14/7.6	16.14
13/5.1	23.50	15/3.2	14.16
13/7.6	22.37	15/7.6	11.61
13/10.2	20.67	15/10.2	10.48

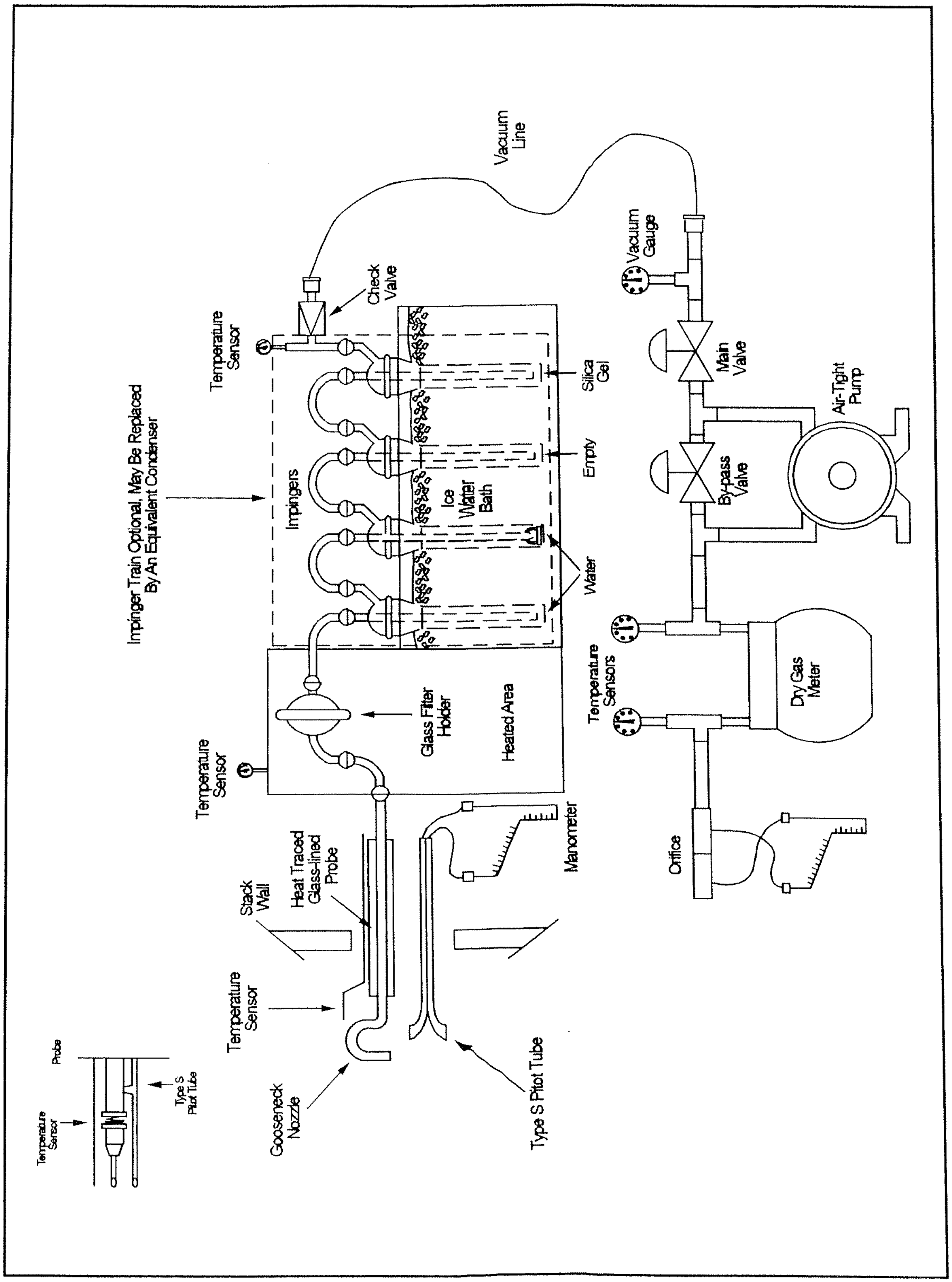

Figure 5-1. Particulate Sampling Train.

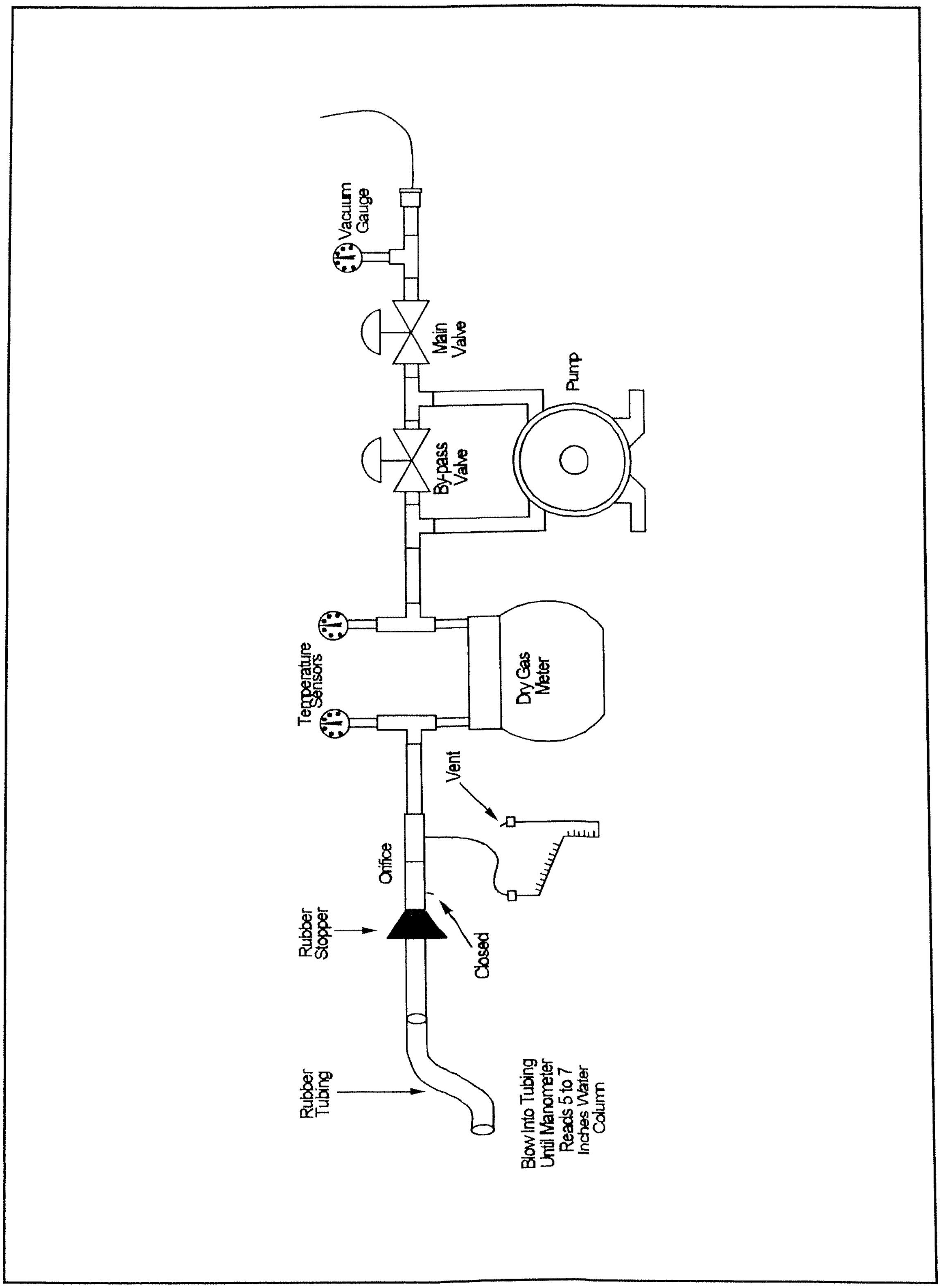

Figure 5-2. Leak Check of Meter Box.

Plant ____________________
Location ____________________
Operator ____________________
Date ____________________
Run No. ____________________
Sample box No. ____________________
Meter box No. ____________________
Meter $\Delta H@$ ____________________
C factor ____________________
Pitot tube coefficient, Cp ____________________

SCHEMATIC OF STACK CROSS SECTION

Ambient temperature ____________________
Barometric pressure ____________________
Assumed moisture, % ____________________
Probe length, (ft.) ____________________
Nozzle Identification No. ____________________
Average calibrated nozzle diameter, (in.) ____________________
Probe heater setting ____________________
Leak rate, (cfm) ____________________
Static pressure, (in. Hg) ____________________
Filter No. ____________________

Traverse point number	Sampling time	Vacuum	Stack temperature	Velocity head	Pressure differential across orifice meter	Gas meter reading	Gas sample temperature at dry gas meter		Filter temperature	Temperature of gas leaving condenser or last impinger
							Inlet	Outlet		
	min.	(in.Hg)	(T_s) (°F)	(ΔP_s) (in. H_2O)	(in. H_2O)	(ft^3)	(°F)	(°F)	(°F)	(°F)
Total							Avg.	Avg.		
Average							Avg.			

Figure 5-3. Particulate Field Data.

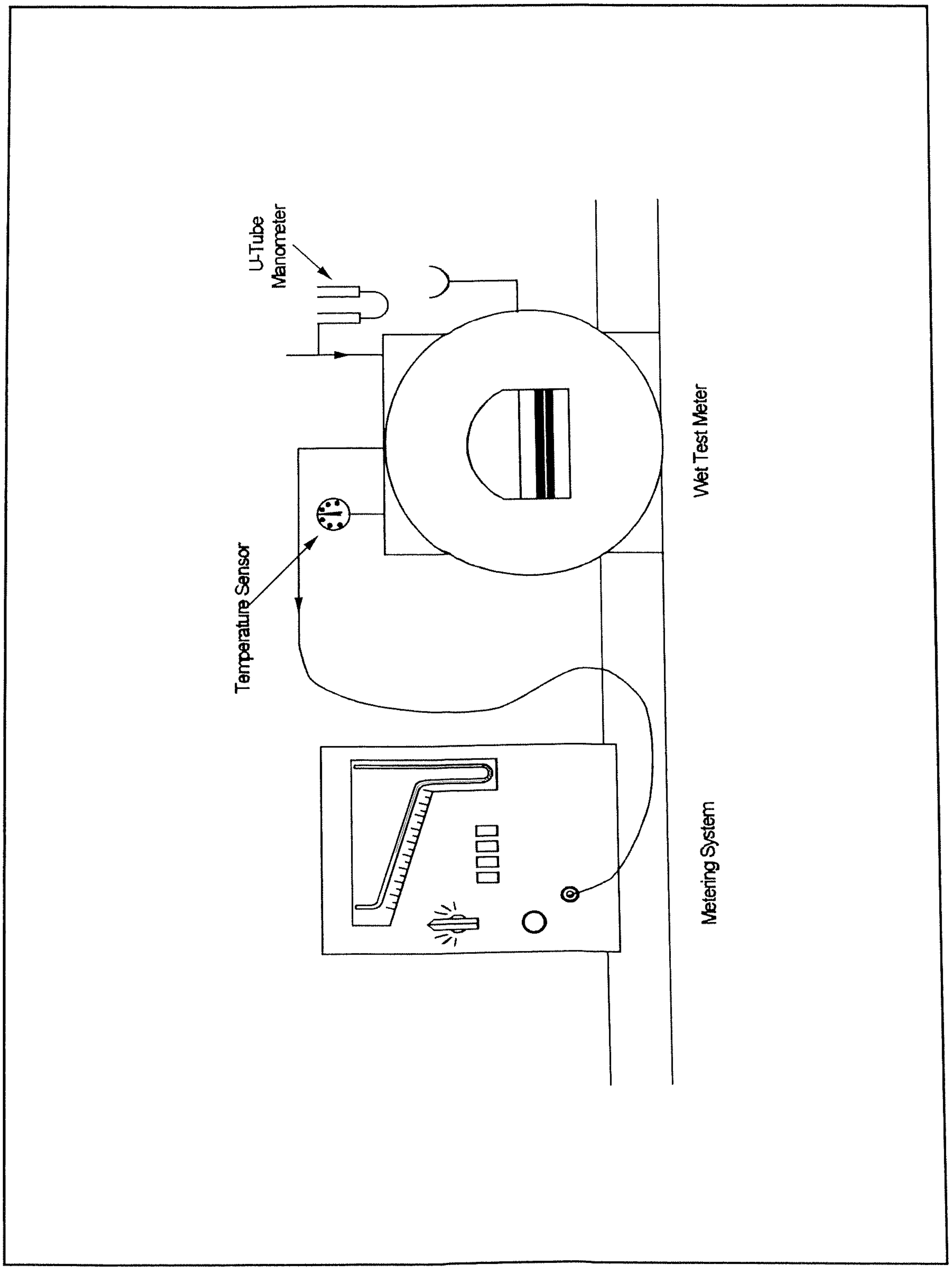

Figure 5-4. Equipment arrangement for metering system calibration.

Date: ______________ Metering System Identification: ________

Barometric pressure, P_b = ________ in. Hg

Orifice manometer setting)H in. H_2O	Spirometer (wet meter) gas volume, V_w ft^3	Dry gas meter volume, V_m, ft^3	Temperatures				Time 1 min
			Spirometer (wet meter) T_w °F	Dry Gas Meter			
				Inlet T_i °F	Outlet T_o °F	Average T_m °F	

Calculations

)H in H_2O	Y				)H@		
Average							

Y = Ratio of reading of wet test meter to dry test meter; tolerance for individual values ± 0.02 from average.

)$H_@$ = Orifice pressure differential that equates to 0.75 cfm of air @ 68 °F and 29.92 inches of mercury, in. H_2O; tolerance for individual values ± 0.20 from average.

Figure 5-5. Example Data Sheet for Calibration of Metering System (English Units).

Plant ______________________________
Date ______________________________
Run No. ______________________________
Filter No. ______________________________
Amount liquid lost during transport ______________
Acetone blank volume, ml ______________
Acetone blank concentration, mg/mg (Equation 5-4) ________
Acetone wash blank, mg (Equation 5-5) ________

Container number	Weight of particulate collected, mg		
	Final weight	Tare weight	Weight gain
1.			
2.			
Total			
Less acetone blank			
Weight of particulate matter			

	Volume of liquid water collected	
	Impinger volume, ml	Silica gel weight, g
Final..........		
Initial........		
Liquid collected		
Total volume collected....		g* ml

*Convert weight of water to volume by dividing total weight increase by density of water (1 g/ml).

$$\frac{\text{Increase, g}}{(1\text{g/ml})} = \text{Volume water, ml}$$

Figure 5-6. Analytical Data Sheet.

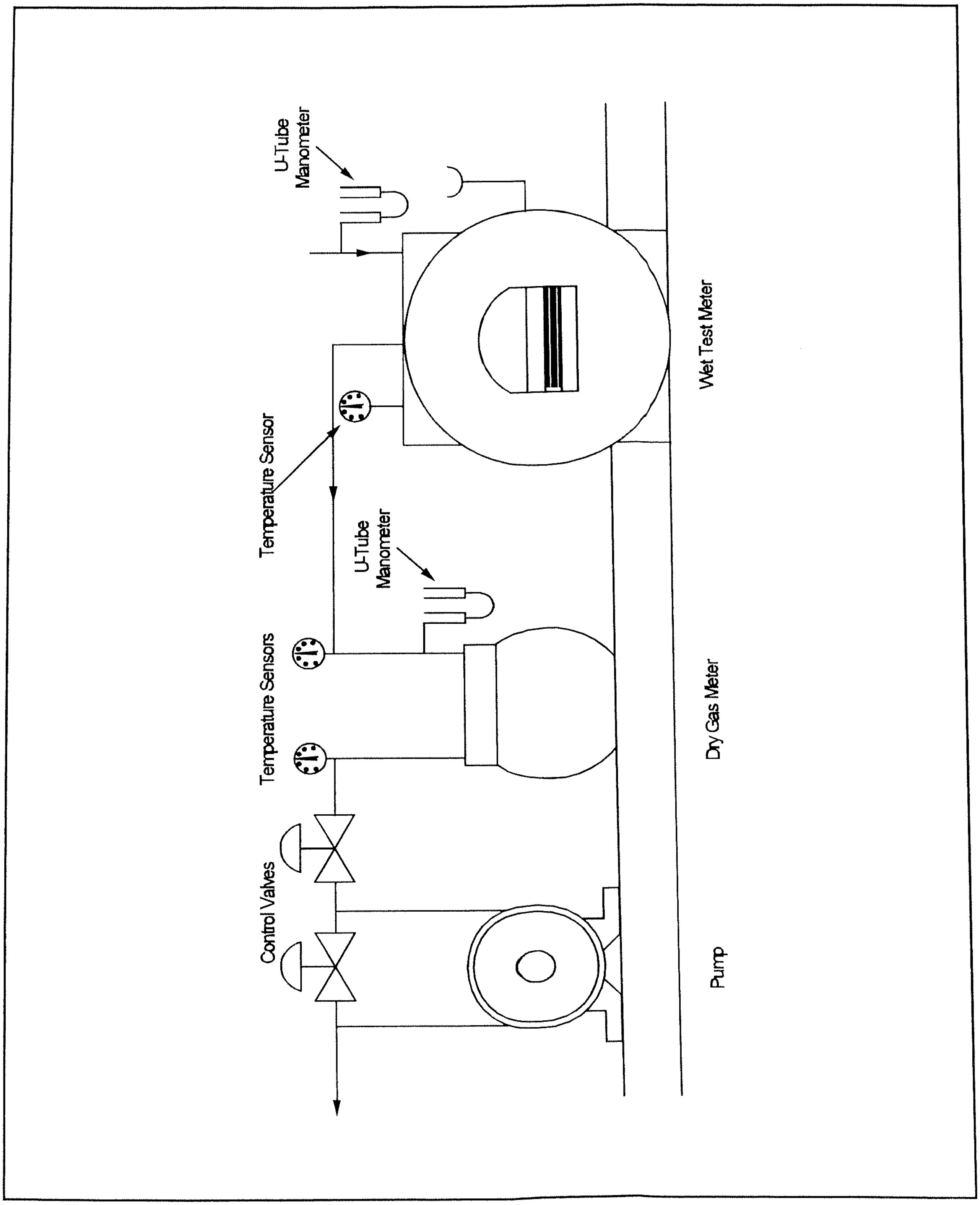

Figure 5-7. Equipment Arrangement for Dry Gas Meter Calibration.

Date: ____________________

Dry Gas Meter Identification: ____________

Barometric Pressure (P): ____________ in. Hg

Approximate Flow Rate ($\bar{Q}$) cfm	Spirometer (Wet Meter) Gas Volume (V_s) ft³	Dry Gas Meter Volume (V_{dg}) ft³	Temperatures: Spirometer (Wet Meter) (t_s) °F	Temperatures: Dry Gas Meter: Inlet (t_i) °F	Temperatures: Dry Gas Meter: Outlet (t_o) °F	Temperatures: Dry Gas Meter: Average (t_d) °F	Dry Gas Meter Pressure (Δp) in. H_2O	Time (q) ft³	Flow Rate (Q) cfm	Meter Coefficient (Y_{ds})	Average Meter Coefficient (Y_{ds})
0.40											
0.60											
0.80											
1.00											
1.20											

$$Q = K_1 \frac{P_{bar} V_w}{(T_w + T_{std} Q)}$$

$$Y_{ds} = \frac{V_w (T_{ds} + T_{std}) P_{bar}}{V_{ds} (T_w + T_{std}) (P_{bar} + \frac{\Delta P}{13.6})}$$

Figure 5-8. Example Data Sheet for Calibration of a Standard Dry Gas Meter for Method 5 Sampling Equipment (English units).

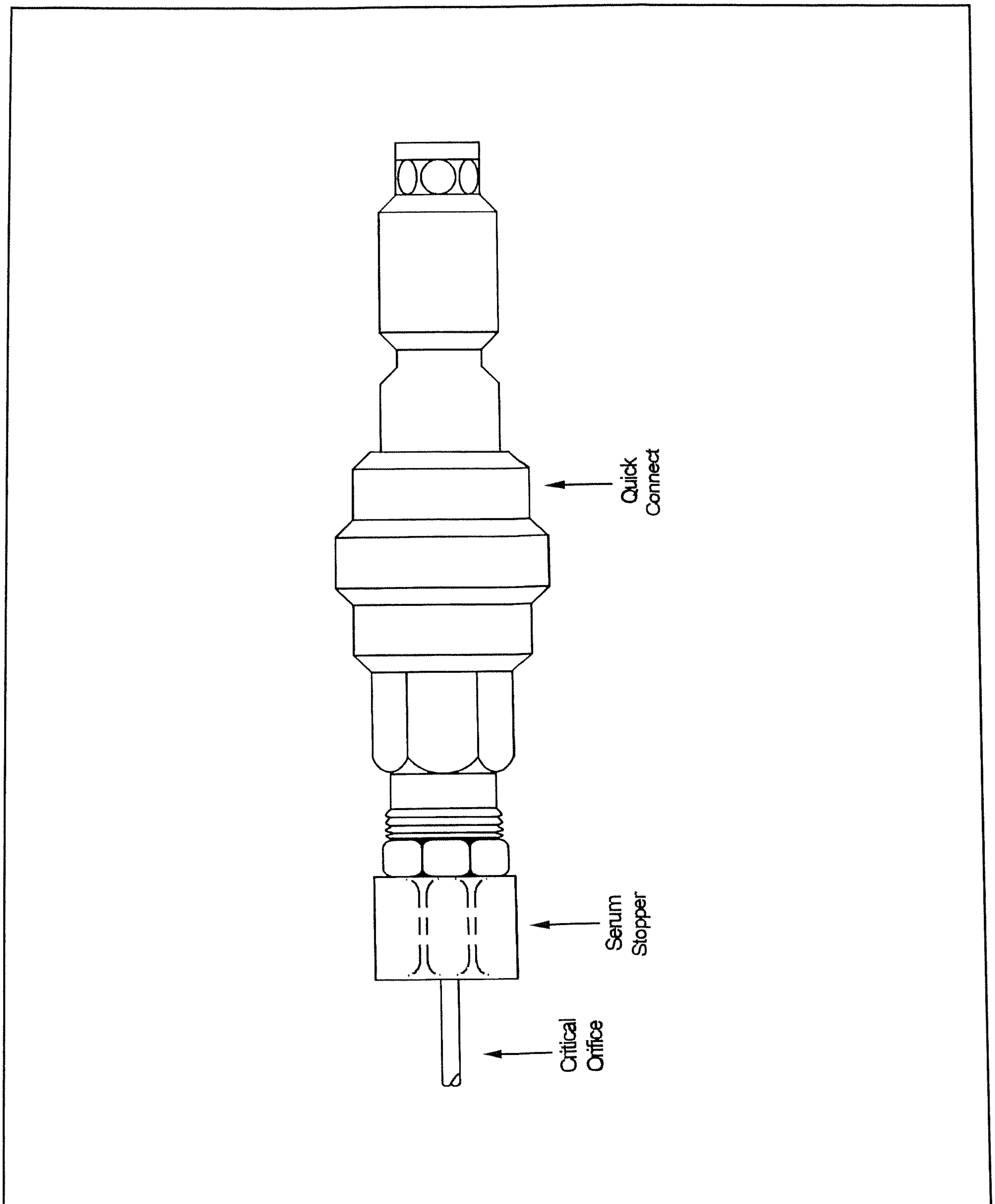

Figure 5-9. Critical Orifice Adaptation to Method 5 Metering System.

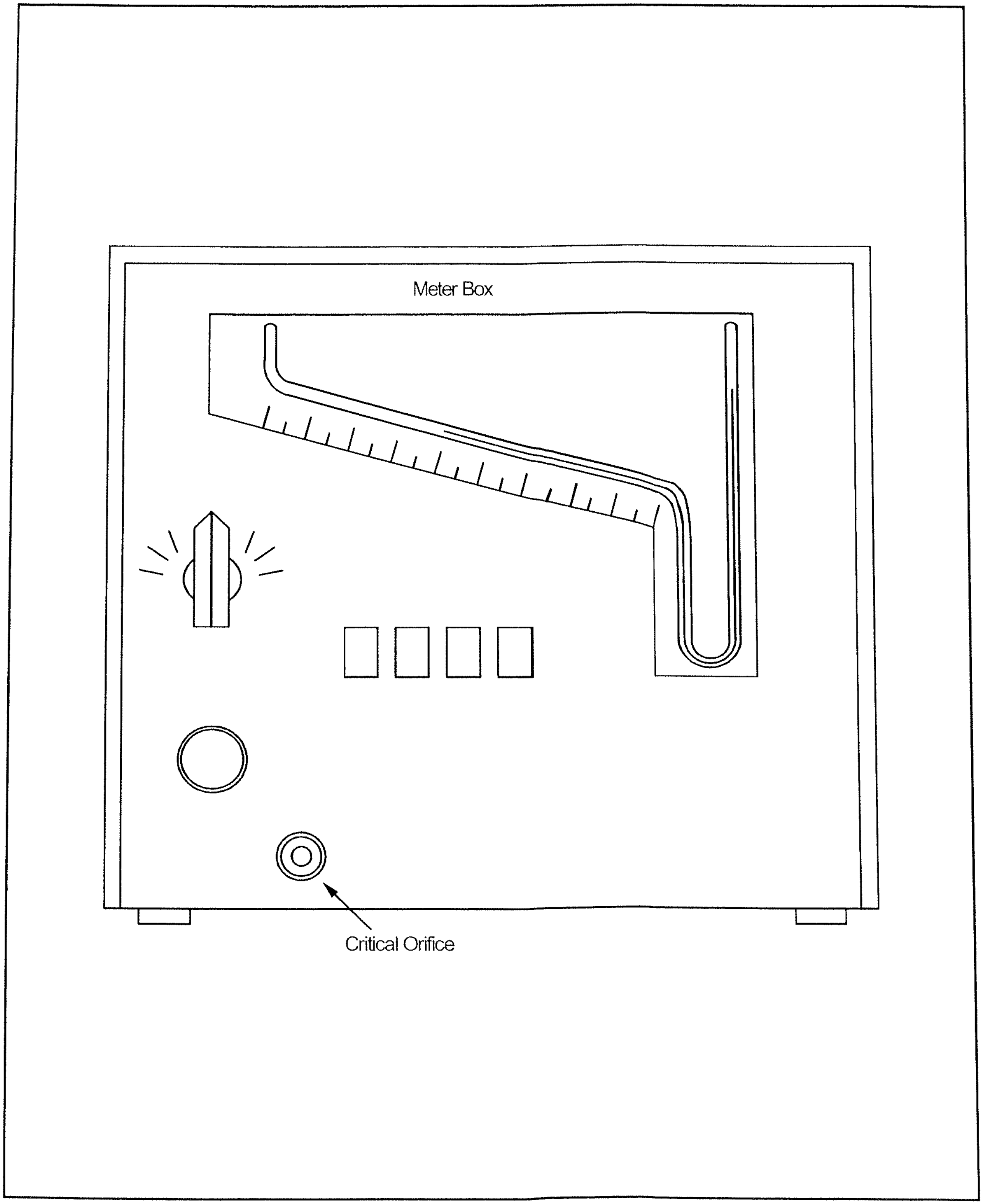

Figure 5-10. Apparatus Setup.

Date ____________________

Train ID ____________________

DGM cal. factor ____________________

Critical orifice ID ____________________

Dry gas meter		Run number	
		1	2
Final reading..........	m^3 (ft^3).......	......	....
Initial reading........	m^3 (ft^3).......	......	....
Difference, V_m.........	m^3 (ft^3).......	......	....
Inlet/Outlet			
temperatures:	°C (°F).......	/	/
Initial..............	°C (°F).......	/	/
.	°C (°F).......	......	....
Final................	min/sec.......	/	/
.	min...........	......	....
Avg. Temperature,			
t_m			
Time, ...			
Orifice man. rdg., H..	mm (in.) H_2O..	......	....
Bar. pressure, P_{bar}....	mm (in.) Hg...	......	....
Ambient temperature,	°C (°F).......	......	....
t_{amb}	mm(in.) Hg...		
Pump vacuum............	....	......	....
K' factor..............	....	......	....
Average..............		......	....
.			

Figure 5-11. Data sheet for determining K' factor.

Date ______________________________

Train ID______________________________

Critical orifice ID _______________

Critical orifice K' factor ________

Dry gas meter		Run number	
		1	2
Final reading	m^3 (ft^3)	.....	.....
Initial reading	m^3 (ft^3)	.....	.....
Difference, V_m	m^3 (ft^3)	.....	.....
Inlet/outlet temperatures:	°C (°F)	/	/
Initial	°C (°F)	/	/
Final	°C (°F)	.....	.....
Avg. Temperature, t_m . .	min/sec	/	/
Time, ...	min	.....	.....
Orifice man. rdg., H . . .	min	.....	.....
Bar. pressure, P_{bar}	mm (in.) H_2O . . .	.....	.....
Ambient temperature, t_{amb}	mm (in.) Hg	.....	.....
Pump vacuum	°C (°F)	.....	.....
$V_{m(std)}$	mm (in.) Hg	.....	.....
$V_{cr(std)}$	m^3 (ft^3)	.....	.....
DGM cal. factor, Y	m^3 (ft^3)	.....	.....
	. . . .	.....	.....

Figure 5-12. Data sheet for determining DGM Y Factor.